<u>Geotechnical Stability Outstanding Data and Information Gaps</u>

- <This Geotechnical Stability section has been prepared based on version 1 of the Geotechnical Data Packages (August/September/October 2011) and November/December 2011 management plans and September 2011 Project Description version 3. PolyMet is in the process of refining the Project Description and are revising the data packages and management plans accordingly. The section will be reviewed and revised as appropriate when version 2 of the Geotechnical Data Packages and revised Project Description and management plans are available.>

- <Draft figures have not been prepared as they are pending information from version 2 of the geotechnical data packages. Figures will be prepared following the receipt of version 2 of the geotechnical data packages.>

- <There may be a future need for version 3 of the geotechnical data packages to complete permitting requirements. The requirement for and timing of these will be better known following the receipt of the version 2 geotechnical data packages.>

5.0 ENVIRONMENTAL CONSEQUENCES

5.2 NORTHMET PROJECT

5.2.14 Geotechnical Stability

The geotechnical stability of the proposed large-scale waste material storage facilities for the NorthMet Project is addressed in this section. These facilities are:

- Mine Site:
    - waste rock Stockpiles;
- Plant Site:
    - Flotation Tailings Basin, and
    - Hydrometallurgical Residue Facility.

Conceptual designs of these proposed large-scale waste material storage facilities (see Chapter 3.0) have been developed through an iterative model and design process to meet the minimum safety factors and water quality criteria as specified by the MDNR.

Results of modeling undertaken by PolyMet for the proposed large-scale waste material storage facilities show that the proposed designs of these facilities would meet the minimum factors of safety in accordance with permitting requirements <to confirm/ revise as appropriate following receipt of version 2 of the geotechnical data package>. The structural integrity of the proposed large-scale waste material storage facilities would also be monitored throughout operations, during closure, and post-closure.

This section provides a summary of the required factors of safety and the methodology and results of the iterative model and design process, as well as an overview of the proposed monitoring and mitigation measures.

5.2.14.1 Methodology and Impact Criteria

The direct environmental consequences of the proposed large-scale waste material storage facilities including the disturbance footprint and water impacts are discussed under the respective environmental factors in Chapter 5.0. This section addresses the structural integrity of the proposed facilities.

If incorrectly designed, constructed, and/or managed, large-scale waste material storage facilities have the potential to be unstable (leading to slope or dam failure) and may also have increased hydrologic and or water quality impacts.

The large-scale waste material storage facilities proposed for the NorthMet Project would require permitting under the MDNR Permit to Mine and Dam Safety Permit, as well as the MPCA State Disposal System Permit. The permits apply design and safety criteria to reduce the risk of potential failure to acceptable levels.

The design of geotechnical features is typically developed using an iterative model and design approach, where the design is amended as required to improve modeling results to meet the required minimum design criteria, including factors of safety. PolyMet is required to provide an adequate level of design and modeling information to the MDNR and MPCA as appropriate for permitting.

The specific design and minimum required factor of safety criteria for the proposed large-scale waste material storage facilities, and the methodology applied to develop the designs of the proposed facilities in order to meet these criteria are discussed for each facility in the respective sections below.

The potential impacts of hypothetical failure scenarios have not been assessed in this SDEIS as the risk of failure is mitigated through application of design and safety requirements.

5.2.14.2 Proposed Action

5.2.14.2.1 Mine Site

The proposed large-scale waste material storage facilities at the Mine Site are (Chapter 3.0):

- a permanent waste rock stockpile for Category 1 waste rock; and
- temporary stockpiles for Category 4 waste rock, combined Category 2/3 waste rock, and an Ore Surge Pile.

The proposed location of these is shown in Figure 5.2.14-1 <to draft this figure once the revised geotechnical data packages are received> which depicts the Mine Site layout at year 11. The temporary Category 4 and Category 2/3 stockpiles would be removed and backfilled to the east pit following year 11.

The geotechnical requirements and design of these are discussed below.

<u>Stockpiles</u>

The data inputs, modeling methodology, results, and design and operating requirements for the stockpiles were reported in Geotechnical Data Package Volume 3 Version 1 (PolyMet 2011a <to revise this reference following the receipt of version 2 of the geotechnical data package>) and reviewed by MDNR Lands and Minerals. The information provided in the data package informs the Permit to Mine.

Design Criteria

Waste rock stockpiles must be designed to comply with *Minnesota Rule* 6132.2400 (stockpile slopes are required to meet *Minnesota Rule* 6132.2400 Subp. 2. B. and stockpile foundations are required to meet *Minnesota Rule* 6132.2400 Subp. 2. A. (1)).

The MDNR requires that the stockpiles are also designed to meet minimum factors of safety for acceptable global stability and foundation stability, the latter of which relates to the capability of the geomembrane liner system to withstand the strain anticipated due to differential settlement that may occur in the stockpile foundation materials. The required minimum factors of safety prescribed for the stockpiles in the NorthMet Geotechnical Modeling Work Plan (MDNR, USACE, USFS 2012) are as follows:

- Long-term (effective stress) operational static for deepseated failures (waste rock mass thickness in excess of 30 feet) factor of safety: ≥1.3.
- Short-term (total stress) operational static for deep-seated failures (waste rock mass thickness in excess of 30 feet) factor of safety: ≥1.1.
- Composite slope (effective stress) pseudo static factor of safety: ≥1.0.
- Composite slope at closure static factor of safety: ≥1.5.
- Composite slope pseudo static at closure factor of safety: ≥ 1.1.

Methodology

In order to demonstrate that the design of the stockpiles would meet the respective geotechnical requirements, PolyMet, in accordance with the NorthMet Geotechnical Modeling Work Plan (MDNR, USACE, 2012):

- gathered existing conditions data (i.e. facility foundation material stratigraphy and strength data and other data as needed to support foundation design) (Section 4.2.14),
- configured stockpile slopes to meet or exceed minimum dimensional requirements established by *Minnesota Rules* 6132.2400,
- performed stockpile subgrade settlement analysis to predict magnitude of deformation and resulting strain in the stockpile liners for comparison to allowable strain in the liner system,
- conducted stability analyses using RocScience's limit equilibrium program SLIDE, and
- defined the stockpile design and operating requirements necessary to maintain required slope stability safety factors and liner performance requirements.

Design

Various design specifications have been established and used for the stockpile analysis (PolyMet 2011a <to revise this reference following the receipt of version 2 of the geotechnical data package>). The following is a summary of the design characteristics applied and considered in modeling.

The Category 1 Stockpile has been designed:

- to be permanent;

- with a maximum lift height of 40 feet, final bench width of 30 feet, initial slopes between benches at the angle of repose of the waste rock and final reclamation slopes between benches of 2.5 (horizontal) to 1 (vertical), as specified in *Minnesota Rule* 6132.2400; and
- to allow for progressive reclamation including grading, contouring, and covering during operation.

<PolyMet are reviewing the design of the Category 1 waste rock Stockpile for water resource protection considerations>

The Category 2/3, and 4 stockpiles, and the Ore Surge Pile have been designed:

- to be temporary;
- to be lined with a Linear low-density polyethylene (LLDPE) geomembrane;
- to have an underdrain system, as required; and
- to have overliner drainage system.

Cross sections of the proposed stockpiles are shown in Figure 5.2.14-2 <to draft this figure once the revised geotechnical data packages are received>

The stability model (SLIDE) assumed a liner interface friction angle (i.e. the indicator of the strength that the liner material poses for resisting one liner material sliding against another liner) of 19 degrees or greater. Further geotechnical investigations of the existing conditions are required to verify the actual liner interface frictional values, as well as the strength parameters for the foundation and stockpile materials prior to construction. To mitigate associated uncertainty at this time, PolyMet commits to remove all unsuitable foundation soils from beneath lined stockpiles and replace them (where required) with structural fill to meet grade requirements (PolyMet 2011b <to revise this reference following the receipt of version 2 of the geotechnical data package>). PolyMet commits to undertaking further geotechnical investigations prior to the construction of the stockpiles to define the foundation management needs.

Modeling Results

The results reported in Geotechnical Data Package Volume 3 Version 1 indicate that the proposed design of the stockpiles would meet all respective factors of safety as required (PolyMet 2011a <to revise this reference following the receipt of version 2 of the geotechnical data package>). The modeling undertaken and results are summarized below.

<u>*Stability*</u>

PolyMet undertook a stability analysis of the five design cross-sections developed to represent the following typical conditions at different phases of stockpile development:

- after year 1, reclaimed configuration;
- after year 1, operational configuration, liner grades of 0% and 0.5%;
- after year 5, reclaimed configuration, stockpile heights of 80 and 120 feet; and
- after year 20, reclaimed configuration.

Assuming a liner interface (i.e. overliner material/LLDPE geomembrane liner/soil liner) friction angle of 19 degrees or greater, results indicated that all design sections met the minimum required factors of safety. Estimated liner strains resulting from foundation settlement are less than 1%; well below the 30% maximum strain allowed in an LLDPE geomembrane proposed for the geomembrane barrier layer component of the basal liner system for the Category 2/3 waste rock Stockpile, Category 4 waste rock Stockpile and the Ore Surge Pile <to revise this paragraph as appropriate following receipt of version 2 of the geotechnical data package>.

Monitoring and Mitigation

A Rock and Overburden Management Plan has been prepared by PolyMet that includes a description of the operating plans, monitoring, and adaptive management approaches for the stockpiles.

The key management measures for the stockpiles relate to monitoring the constructed side slopes and dimensions, as well as type and volume of waste rock and overburden predicted as well as that actually stockpiled to monitor that the stockpile designs as well as material requirements for backfilling to the East Pit void (when available) are sufficient. The stockpile quantities would be monitored throughout the life of the mine and the stockpile heights and footprints would be monitored to verify that they are constructed as planned. Monitoring and maintenance of the Category 1 waste rock Stockpile would also continue through the post-closure period until the MDNR determines that the cover is stable and self sustaining. An annual compliance report would be developed each year for submittal to the MDNR to comply with the Permit to Mine requirements.

Information gained through ongoing monitoring would also be used to advise adaptive waste management requirements including potential expansion of the waste rock stockpiles and/or disposal of some of the waste rock or saturated overburden in the West Pit in areas where mining has ceased.

Each year a plan comparison would be completed, as required for the Permit to Mine, to keep the Rock and Overburden Management Plan document current and to track changes in the mine plan, rock schedule, and characterization of the material. Modifications to the Rock and Overburden Management Plan based on changes to the material characterization would be completed, as necessary.

5.2.14.2.2 Transportation and Utility Corridor

The proposed Transportation and Utility Corridor does not include the creation or modification of any large-scale waste management facilities or other large-scale geotechnical features.

5.2.14.2.3 Plant Site

The large-scale waste material storage facilities proposed at the Plant Site are the Tailings Basin and the Hydrometallurgical Residue Facility (Chapter 3.0).

The Tailings Basin would be constructed on top of Cell 1E and Cell 2E of the existing LTVSMC tailings facility. The Hydrometallurgical Residue Facility would be located at the site of the LTVSMC Emergency Basin, adjacent to the southern extent of LTVSMC tailings Cell 2W (Figure 5.2.14-3 <to draft this figure once the revised geotechnical data packages are received>). The existing geotechnical conditions at these sites are discussed in Section 4.2.14.

Tailings Basin

The data inputs, modeling methodology, results, and design and operating requirements for the Flotation Tailings Basin were reported in Geotechnical Data Package Volume 1 Version 1

(PolyMet 2011b <to revise this reference following the receipt of version 2 of the geotechnical data package>) and reviewed by MDNR. The information provided in the data package informs the permitting process and is summarized below.

Design Criteria

In Minnesota, dams must be constructed in accordance with applicable requirements of *Minnesota Administrative Rules* 6115.0300 through 6115.0520 – Dams. Portions of the rules are applied universally, while applicability of some rule requirements is dependent on the hazard classification of the dams.

The MDNR requires that the most sensitive slope cross-section of the Tailings Basin is demonstrated to meet or exceed the following minimum factors of safety as required for various construction and loading scenarios (such as various dam and pond elevations during construction and closure). The slope stability analysis requirements prescribed in the NorthMet Geotechnical Modeling Work Plan (MDNR, USACE, USFS 2012) are as follows:

- Effective Stress Stability Analysis (ESSA) – factor of safety ≥1.5 for effective shear strength conditions using drained parameters.
- Undrained Strength Stability Analysis (USSA) – factor of safety ≥1.3 for undrained shear strength conditions for non-statically liquefiable soils (i.e. end of construction case per dam raise).
- Liquefaction Analysis USSA:
    - Static Liquefaction (i.e. induced by over steepening of slopes or pond bounce) Factory of Safety (flow) ≥1.2; and
    - Seismic Liquefaction (i.e. induced by seismic event) factor of safety (flow) ≥1.2 (or if the results of deformation modeling is accepted by the MDNR if Factor of safety is >1.0).

These minimum factors of safety have been selected to account for the variability in material characteristics.

Methodology

In order to demonstrate that the design of the Flotation Tailings Basin would meet the respective geotechnical requirements, PolyMet, in accordance with the NorthMet Geotechnical Modeling Work Plan (MDNR, USACE, USFS 2012):

1. Gathered conditions data (i.e. existing basin topography, stratigraphy, soil and tailings strength and hydraulic characteristics, characteristics of NorthMet tailings based on those produced during the pilot-plant processing, and other data as needed to support geotechnical modeling and Tailings Basin design) (Section 4.2.14).
2. Developed Tailings Basin slope cross-sections (i.e. geometry and stratigraphy for existing and planned conditions) for the Tailings Basin for seepage and stability modeling.
3. Developed seepage and stability models using Geo-Slope International, Inc. modeling software (i.e. SLOPE/W, SEEP/W and SIGMA/W as necessary) for various construction and loading scenarios (such as various dam and pond elevations during construction and closure).
4. Established the geotechnical design data for model input including identification of strength parameters, and the triggering potential for static and seismic events.

5. Ran the models and performed a sensitivity analysis.
6. Refined the design and operating requirements necessary to maintain required slope stability safety factors and deformation requirements for the critical slope cross-section.

Design

<To revise this section as appropriate following receipt of version 2 of the geotechnical data package.>

The proposed tailings basin would be constructed using upstream methods where dams are raised (using LTVSMC tailings) in stages on top of the previous dam and tailings are deposited towards the center of the basin from spigots at the dam's edge (Figure 3.2-15). Tailings will also be discharged subaqueously in the basin via a barge.

Various design specifications have been established and used for Tailings Basin geotechnical analysis (PolyMet 2011b <to update this reference following receipt of the version 2 geotechnical data package>). The following is a summary of the design characteristics applied and considered in modeling.

The proposed Tailings Basin incorporates construction of new dams over the existing LTVSMC Cells 1E and 2E. The design process involved an iterative approach whereby various combinations of stabilization factors including slope angle, lift offsets and height, bench width, foundation layers, and buttresses were modeled to identify a design that would:

- provide safe permanent storage of tailings generated over the proposed 20 year operating life of the NorthMet Project;
- efficiently and effectively recover process water from the surface of the Tailings Basin during operation;
- accommodate the planned wet cover system at closure; and
- meet project regulatory requirements (including factors of safety).

The proposed design consists of eight lifts with an ultimate crest elevation (selected on the basis of tailings storage capacity requirements) modeled as 1,732 feet AMSL. This would be 150 feet on top of the existing LTVSMC tailings Cell 2E. This proposed elevation is similar to the elevation of the existing north dam of Cell 2W, which is at an ultimate elevation of 1,735 feet AMSL (Figure 3.2-15).

Before placement of tailings, LTVSMC course tailings sourced from the existing tailings basin would be used to construct a foundation layer to maintain a lowered phreatic surface within the new dam. Additional modeling would be conducted to ascertain if this foundation layer needs to be continuous along the length of the dam, or if narrow segments of foundation material would also be effective. Rock buttresses would be placed at the northern toe of the existing Cell 2E starter dam, and at the south end of Cell 1E near the railroad fill to provide a counterweight to the driving forces increased by the dam raises. The model assumes that any peat at the toe of the north dam below the proposed location of the buttress would be removed prior to construction, to allow the buttress to key into the stronger underlying glacial till. Buttress material would likely consist of waste rock from a nearby stockpile.

The new dams would be made from mechanically placed and compacted borrowed LTVSMC bulk tailings (supplemented with material sourced off-site if required) as needed to yield the desired dam lift height and geometry. The exterior face of the dams would be augmented with a bentonite layer as they are constructed to limit oxygen and rain water infiltration into the dams.

The lifts would have slopes of 4.5H:1V on the outside of the basin and 2H:1V on the inside. Each lift would be 20 feet high (although each lift may be subdivided into several smaller lifts), with the exception of the last lift, lift 8, which would be only 10 feet in height. Each lift would have a 200 foot wide base, and a 60-foot bench from the outside edge of the previous lift to the toe of the new lift, with the exception of lift 5, which requires an offset of 260 feet. This mid-slope setback was included to flatten the overall slope angle and push the driving forces at the higher lifts farther from the toe of the Tailings Basin. This setback was modeled to be covered with LTVSMC tailings and could be used to support a rock buttress if required for additional stability if identified as being required in the future (not currently proposed).

As dams are constructed, exterior slopes would be stabilized and vegetated. Upon completion of ore processing operations (after 20 years of operation), the Tailings Basin would be closed in accordance with *Minnesota Rules* 6132.3200 and would also include <water management at the Tailings Basin including engineering controls during operation and closure is being reviewed by PolyMet. This section (and the chapter as a whole) needs to be revised accordingly following finalization of the project description and management plans>:

- bentonite augmentation of the pond area bottom to reduce infiltration to a sufficient degree to maintain desired pond water elevations at closure;
- bentonite augmentation of the exposed beach area; and
- establishment of wetland vegetation in transition areas between the beach and pond area.

Figure 5.2.14-4 <to draft this figure once the revised geotechnical data packages are received>) shows the development and layering of tailings along Cross-Section F (Figure 5.2.14-3 <to draft this figure once the revised geotechnical data packages are received>).

Drawings showing the Tailings Basin at closure are provided in Figure 5.2.14-5 <to draft this figure once the revised geotechnical data packages are received>

Identification of the Critical Cross Section

Cross-Section F (Figure 5.2.14-3 <to draft this figure once the revised geotechnical data packages are received>) is considered to be the most critical cross-section as it is anticipated to yield the lowest slope stability safety factor due to a peat layer at the toe of the initial dam (Section 4.2.14).

Section F was analyzed in a sequential manner consisting of development of the dam cross-section stratigraphy for analyses, application of the material strength and permeability characteristics, modeling of seepage conditions at the dam cross-section, followed by performance of stability analyses.

Once the preliminary Section F configuration was determined, Cross-Section F was evaluated with the Tailings Basin at the ultimate crest height to determine whether liquefaction would be triggered in the contractive materials, based on certain triggers prescribed in the NorthMet Geotechnical Modeling Work Plan (MDNR, USACE, USFS 2012). Analyses of additional cross-sections would be required prior to permitting <to revise the text here as appropriate following confirmation as to when further cross-section will be analyzed>.

Modeling Results

<To confirm/ revise this section as appropriate following receipt of version 2 of the geotechnical data package>

The results reported in Geotechnical Data Package Volume 1 Version 1 indicate that the proposed design of the Tailings Basin would meet all respective factors of safety as required (PolyMet 2011b <to revise this reference following the receipt of version 2 of the geotechnical data package>). The modeling undertaken and results are summarized below.

Slope Stability

<To revise this section as appropriate following receipt of version 2 of the geotechnical data package>

The predicted factor of safety values for Cross-Section F at the ultimate height of the dam (year 20) are summarized in Table 5.2.14-1. All slope stability factors are modeled to meet the factors of safety required by the MDNR.

Table 5.2.14-1 Stability Modeling Results for Proposed Final Lift Conditions (Cross-Section F) < to revise the results as appropriate following receipt of version 2 of the geotechnical data package>

Case	Slip Surface	Peak USSA			ESSA
		High	Average	Low	
Required Minimum Factor of Safety:			1.3		1.5
At proposed end of mine life (maximum construction) with a normal pond height	Circular[1]	2.07	1.90	1.72	3.20
	Optimized[2]	1.75	1.62	1.48	3.04
	Wedge[3]	1.75	1.84	1.84	3.16
At proposed end of mine life (maximum construction) with maximum pond (after probable maximum precipitation event)	Circular[1]	Not Available	1.88	Not Available	3.20
	Optimized[2]	Not Available	1.61	Not Available	3.03
	Wedge[3]	Not Available	1.83	Not Available	3.13

Notes:
1: Assumes failure of a soil mass would occur as though it is rotating within a larger mass
2: Assumes that failure of a soil mass could occur in any manner
3: Assumes failure of a soil mass would occur as a large, monolithic block (wedge) sliding relative to the surrounding soil mass

Liquefaction

<To revise this section as appropriate following receipt of version 2 of the geotechnical data package>

Liquefaction was not triggered in any of the methods analyzed using average USSA strengths (Table 5.2.14-2).

Table 5.2.14-2 Liquefaction Triggering Results for Proposed Conditions (Cross-Section F) <to revise the results as appropriate following receipt of version 2 of the geotechnical data package.>

Method	Case	Minimum Required factor of safety	Predicted average factor of safety for Triggering Liquefaction
Seismic estimation	Farfield (higher magnitude earthquakes caused by the New Madrid Seismic Zone)	1.2	1.76
	Nearfield (low-level earthquakes with epicenters in the Midwest)	1.2	1.86
	Combined	1.2	1.86
Seismic Modeling	Farfield (higher magnitude earthquakes caused by the New Madrid Seismic Zone)	1.2	1.58
	Nearfield (low-level earthquakes with epicenters in the Midwest)	1.2	1.79
	Combined	1.2	1.79
Static	Probable maximum precipitation event	1.2	1.84
	Steepened Slopes	1.2	1.73

Monitoring and Mitigation

Geotechnical investigations performed on the Tailings Basin during operations would be used to reanalyze the design based on actual observed conditions during construction. As discussed further below, construction and monitoring reports describing the specifications and conditions of the built facility would be provided to the MDNR Commissioner in accordance with the conditions of permits.

A Flotation Tailings Management Plan has been prepared by PolyMet that includes a description of the operating plans, monitoring, and adaptive management approaches for the Tailings Basin.

The Tailings Basin would be monitored using dam monitoring instrumentation and systematic dam safety inspections. Existing and proposed geotechnical instrumentation would measure the tailings dam performance that is estimated to occur (through stability, seepage, and deformation modeling completed as part of Dam Safety permitting), and that which is actually occurring. Monitoring instrumentation relevant to geotechnical stability would include:

- **piezometers** to facilitate monitoring of the phreatic surface within the dams (the phreatic surface has a significant impact on slope stability) – to be compared to that modeled;
- **inclinometers** to facilitate monitoring of the movement of the Tailings Basin dams – compared to that modeled;
- **survey monitoring points** to facilitate the monitoring of horizontal and vertical deformation of the Tailings Basin dams; and
- **vibrating wire technology** may be utilized to obtain semi-continuous measurements of pore water pressure and slope inclination.

Observational monitoring regimes would include:

- Opportunistic observations by on-site staff to observe and report any suspicious conditions.
- Weekly / daily routine dam inspections to observe the conditions and performance of the Tailings Basin dams and associated facilities so that any changes to dam conditions, performance, or potentially hazardous conditions could be identified and promptly addressed.
- Dam Safety Inspections (DSI) to evaluate, on a regular basis, the current and past performance of the Tailings Basin dams and to observe potential deficiencies in their condition, performance, and/or operation.
- Five yearly Routine Dam Safety Reviews (DSRs) to ascertain that the dam has an adequate margin of safety, based on the current Dam Safety Permit, current engineering practice, and updated operations and design input data. A DSR may also be carried out to address a specific problem.
- Periodic evaluation of tailings dam stability by a qualified geotechnical engineer would also occur after closure at a frequency and for the duration required by the facility Dam Safety Permit.

Typical maintenance of the facility would include repairing eroded surfaces and repair and replacement of damaged monitoring and operational infrastructure. The majority of the non-mechanical maintenance work at the Tailings Basin would be carried out on an as-required basis, rather than on a scheduled basis because it is driven by weather events rather than hours of operation. Mechanical components would be incorporated into a planned inspection and maintenance program.

PolyMet has prepared an Emergency Action Plan (EAP) to provide guidance to on-site personnel and emergency responders in the case of unplanned occurrences at the Tailings Basin. The EAP identifies and specifies initial actions in response to a variety of occurrences representing differing levels of severity and complexity.

Annual reports on the conditions of the Tailings Basin would be required under the MDNR Dam Safety Permit and Permit to Mine. Monitoring and maintenance would continue post-closure in accordance with permit requirements.

<u>Hydrometallurgical Residue Facility</u>

The data inputs, modeling methodology, results, and design and operating requirements for the Hydrometallurgical Residue Facility were reported in Geotechnical Data Package Volume 2 Version 1 (PolyMet 2011c <to revise this reference following the receipt of version 2 of the geotechnical data package>) and reviewed by MDNR. The information provided in the data package informs the permitting process and is summarized below.

Design Criteria

The design of the Hydrometallurgical Residue Facility must meet the applicable requirements of *Minnesota Administrative Rules* 6115.0300 through 6115.0520 and the requirements of the NorthMet Geotechnical Modeling Work Plan (MDNR, USACE, USFS 2012) which includes:

- the ability of the most sensitive slope cross-section to meet a global slope stability factor of 1.5;
- the ability of the composite liner system to comply with infinite slope stability safety factor of 1.5; and

- the capability of the composite liner system to withstand the strain anticipated due to differential settlement that may occur in the facility foundation materials.

Methodology

To demonstrate that the design of the Hydrometallurgical Residue Facility would meet the respective geotechnical requirements, and in accordance with the NorthMet Geotechnical Modeling Work Plan (MDNR, USACE, USFS 2012), PolyMet:

1. Gathered existing conditions data (i.e. facility foundation material stratigraphy and strength data, hydrogeological data, characteristics of NorthMet residues based on those produced during the pilot-plant processing, and other data as needed to support geotechnical modeling of the Hydrometallurgical Residue Facility) (Section 4.2.14).
2. Developed residue facility layout and slope cross-sections (i.e. geometry and stratigraphy for existing and planned conditions) for proposed residue facility stability and deformation modeling.
3. Developed seepage and stability models using Geo-Slope International, Inc. modeling software (i.e. SLOPE/W, SEEP/W and SIGMA/W as necessary) for various construction and loading scenarios (such as various dam and pond elevations during construction and closure).
4. Established the geotechnical design data for model input including identification of strength parameters, and the triggering potential for static and seismic events.
5. Ran the models to determine factors of safety, and the potential for slope failure and deformation of the foundation and liner.
6. Refined the design and operating requirements necessary to maintain required slope stability safety factors and deformation requirements for the critical slope cross-section.

Design

<To revise this section as appropriate following receipt of version 2 of the geotechnical data package.>

Various design specifications have been established and used for the Hydrometallurgical Residue Facility geotechnical analysis (PolyMet 2011c <to revise this reference following the receipt of version 2 of the geotechnical data package>). The following is a summary of the design characteristics applied and considered in modeling.

The Hydrometallurgical Residue Facility has been designed as a single cell structure with a 20 year design capacity of 6,500,000 cubic yards to be located on top of the LTVSMC Emergency Basin. The perimeter would have an irregular shape consisting of the North Dam, natural high ground, and new dams (Figure 5.2.14-3 <to draft this figure once the revised geotechnical data packages are received>)

The maximum height of the proposed dams is approximately 55 feet with a crest elevation of 1,650 feet. The exterior, downstream, face of the dam would be constructed at a slope of 3 horizontal to 1 vertical (3:1).The interior of the Hydrometallurgical Residue Facility would be sloped at 3.5H:1V <to confirm this following receipt of version 2 of the geotechnical data package (Hydrometallurgical Residue Facility)> and 30-foot horizontal benches would be placed at elevations of 1,600 and 1,630 feet.

Prior to construction of the dams, PolyMet would:

1. install geogrid reinforcement and a granular drainage layer at the existing Emergency Basin, as needed to facilitate wick drain installation;
2. install wick drains; and
3. place, monitor, and remove a surcharge load fill in the LTVSMC Emergency Basin to pre-consolidate existing material, thereby limiting the potential future strains.

The dams would be constructed in three primary phases (year 1, year 4, and year 11) to allow for the phased installment of a double liner system. The geosynthetic liner system will consist of the following components, listed in order from top to bottom (Figure 5.2.14-6 <to draft this figure following receipt of version 2 of the geotechnical data package>):

1. upper geomembrane,
2. geocomposite (geonet) (for drainage),
3. lower geomembrane, and
4. geosynthetic clay liner.

The dams would be constructed using downstream construction methods that involve constructing the interior segments of the dam first and then raising the dam upward and outward from the center of the cell as additional capacity is needed. Construction material would be sourced from natural soil and quarried bedrock between the high ground and South Dam. Some LTVSMC coarse tailings may also be utilized for dam construction. While the material is placed, it would be compacted to the design density.

Identification of the Critical Cross Section

Cross-Section AA <nomenclature for cross-section need to be confirmed following receipt of the revised geotechnical data packages.> (Figure 5.2.14-3 <to draft this figure once the revised geotechnical data packages are received>) has been identified as the critical cross-section. It approximates the base a former ravine, beginning south of the future southern dam and terminating near the crest of the Hydrometallurgical Residue Facility North Dam. It is considered to be the most critical cross-section as it incorporates the thickest sections of LTVSMC slimes. Fine tailings and slimes in the Emergency Basin are the thickest at approximately 50 feet at Node A <nomenclature for cross-section needs to be confirmed following receipt of the revised geotechnical data packages> located 280 feet away from the toe of the South Dam (Figure 5.2.14-3 and Figure 5.2.14-7 <to draft this figure once the revised geotechnical data packages are received>). A cross-section of the proposed Hydrometallurgical Residue Facility at its maximum extent along Cross-Section AA<nomenclature for cross-section needs to be confirmed following receipt of the revised geotechnical data packages> is shown in Figure 5.2.14-7 <to draft this figure once the revised geotechnical data packages are received>.

The global slope stability discussed below was assessed along Cross-Section AA <nomenclature for cross-section needs to be confirmed following receipt of the revised geotechnical data packages>. Analyses of additional cross-sections would be required to support the permitting process <to revise the text here as appropriate following confirmation as to when further cross-section will be analyzed>.

Modeling Results

The results reported in Geotechnical Data Package Volume 2 Version 1 indicate that the proposed design of the Hydrometallurgical Residue Facility would meet all respective factors of safety as required (PolyMet 2011c <to revise this reference following the receipt of version

2 of the geotechnical data package>). The modeling undertaken and results are summarized below.

Stress Deformation

<To revise this section as appropriate following receipt of version 2 of the geotechnical data package>

As a result of applying a surcharge load to the LTVSMC Emergency Basin, the maximum vertical settlement estimated for the Hydrometallurgical Residue Facility was 1.4 feet at Node A.

Residue consolidation would begin at the onset of cell dewatering at closure. Over time the rate of consolidation would decrease with the greatest amount of consolidation occurring within the first 20 years following closure. Total settlement in areas with the greatest depth of residue is estimated to be on the order of 3.3 feet. As the depth of residue decreases near the edge of the Hydrometallurgical Residue Facility, less settlement would occur. The resulting deformed surface of the Hydrometallurgical Residue Facility would be concave upward with the greatest deformation in areas of greatest residue thickness.

Strain in the Hydrometallurgical Residue Facility liner system would result from differential settlement between points along the liner interface with the foundation materials. The maximum strain in the liner system is estimated to be 0.20 percent. This value is well within tolerable limits of most geosynthetics which range from 1 to 19 percent.

Global Slope Stability

<To revise this section as appropriate following receipt of version 2 of the geotechnical data package.>

Analysis of the new dams (i.e. not those supported by the existing LTVSMC tailings basin or natural topography) when they are at their greatest height (at year 20) predicted the factor of safety to be 1.98, which is greater than the requirement minimum of 1.5. Because the angle of repose for the dam fill (approximately 30 degrees) is greater than the proposed dam downstream slope angle (18 degrees), surficial slope failures are not expected.

Because the material in the constructed dams are proposed to be well compacted and because the Hydrometallurgical Residue Facility liner system would preclude leakage through the dams, Undrained Strength Stability Analysis (USSA) and Liquefaction Analysis (USSAliq) were not applicable and were not performed.

Infinite Slope Stability – Geosynthetic Liner System

<To revise this section as appropriate following receipt of version 2 of the geotechnical data package.>

The components of the double liner system are designed to act as hydraulic barriers to leakage; not as structural members of the dam system. Therefore, the liner layers must not be allowed to slide relative to one-another. Evaluation of this potential for sliding was performed using infinite slope stability analyses. The minimum infinite slope stability safety factor for all Hydrometallurgical Residue Facility liner system components is greater than 1.5. On the basis of the interface friction angles used in the analysis, the design proposed for the Hydrometallurgical Residue Facility achieves a computed safety factor of 1.63 or greater for all Hydrometallurgical Residue Facility liner system components. Interface friction angles would require confirmation upon bidding of Hydrometallurgical Residue Facility construction and corresponding selection of material suppliers.

The interior slope angle for the Hydrometallurgical Residue Facility and the geosynthetic materials of the liner that would directly contact the underlying soils used for dam construction must be selected to yield a stable liner system – a system that would not slide down-slope as the Hydrometallurgical Residue Facility is filled with residue. In addition, each successive layer of the liner system must have an adequate interface-friction angle with the underlying layer to prevent down-slope movement of any layer of the liner system. Infinite slope stability for the liner system layer interfaces are shown in Table 5.2.14-3. The liner interfaces are shown in Figure 5.2.14-6 <to draft this figure once the revised geotechnical data packages are received>. Computed factors of safety shown in Table 5.2.14-3 are based on commonly reported interface friction angles between the materials anticipated to be used for the Hydrometallurgical Residue Facility liner. Any variation from the anticipated material types warrants project-specific interface shear testing to confirm that the friction angles are equal or greater than those used in this analysis.

Table 5.2.14-3 Infinite Slope Stability Analysis Results < to revise these results as appropriate following receipt of version 2 of the geotechnical data package>

Interface Number	Material Types	Slope Angle, (deg)	Predicted friction Angle, (deg)	Minimum required factor of safety	Predicted factor of safety
4	Textured Geomembrane above Geocomposite Drainage Net	15.95	26	1.5	1.63
3	Geocomposite Drainage Net above Textured Geomembrane	15.95	26	1.5	1.63
2	Textured Geomembrane above Geosynthetic Clay Liner	15.95	26	1.5	1.63
1	Geosynthetic Clay Liner above Granular Soil	15.95	32	1.5	2.01

Monitoring and Mitigation

A Hydrometallurgical Residue Management Plan has been prepared by PolyMet that includes a description of the operating plans, monitoring and adaptive management approaches for the Hydrometallurgical Residue Facility.

Monitoring and maintenance for the Hydrometallurgical Residue Facility would be similar to that discussed for the Tailings Basin above.

5.2.14.3 No Action Alternative

5.2.14.3.1 Mine Site

Under the No Action Alternative, no large-scale waste material storage facilities would be created. The existing environment would remain in-situ and there would be no change in the geotechnical stability. The existing geotechnical conditions are discussed in Section 4.2.14.

5.2.14.3.2 Plant Site

Under the No Action Alternative, no new tailings large-scale waste material storage facilities would be created. The existing LTVSMC tailings facility as discussed in Section 4.2.14 would remain at the site and would be managed under the Consent Order.

Stability modeling undertaken for conditions at Cross-Section F (critical cross-section) measured at the end of LTVSMC operations in 2001 determined that all safety factors were above the recommended minimum values (Table 5.2.14-4). Monitoring and inspection would continue under the LTVSMC site closure plan and the MDNR dam safety regulations.

Table 5.2.14-4 Stability Model Results for 2011 (Section F) <to revise these results as appropriate following receipt of version 2 of the geotechnical data package>

CASE	Slip surface	Peak USSA			ESSA
		High	Average	Low	
Minimum required factor of safety			1.3		1.5
Existing Conditions	Circular[1]	2.06	1.94	1.87	2.11
	Optimized[2]	2.19	2.16	2.13	2.25
	Wedge[3]	2.37	2.24	2.13	2.53

Notes:
1: Assumes failure of a soil mass would occur as though it is rotating within a larger mass
2: Assumes that failure of a soil mass could occur in any manner
3: Assumes failure of a soil mass would occur as a large, monolithic block (wedge) sliding relative to the surrounding soil mass

5.3 LAND EXCHANGE

5.3.14 Geotechnical Stability

Geotechnical stability considerations for the proposed waste rock stockpiles that would be located on federal land subject to the proposed Land Exchange at the NorthMet Mine Site are discussed in Section 5.2.14. There are no other existing or proposed large-scale waste material storage facilities on land subject to the proposed Land Exchange.

DRAFT FIGURE LIST

<To draft figures following the receipt of version 2 of the geotechnical data packages>

Figure Number	Description/title
5.2.14-1	Proposed Mine Site Layout (Year 11) <to prepare this figure following the revised project description and geotechnical data packages>
5.2.14-2	Cross Sections of the Proposed Stockpiles at Maximum Size <to prepare this figure following the revised project description and geotechnical data packages>
5.2.14-3	Proposed Plant Site Layout <to prepare this figure following the revised project description and geotechnical data packages>
5.2.14-4	Cross-Section F of the Proposed Tailings Basin at Maximum <to prepare this figure following the revised project description and geotechnical data packages>
5.2.14-5	Proposed Closure Conditions at the Tailings Basin <to prepare this figure following the revised project description and geotechnical data packages>
5.2.14-6	Proposed Double Liner System at the Hydrometallurgical Residue Facility <to prepare this figure following the revised project description and geotechnical data packages>
5.2.14-7	Cross Section AA of the Proposed Hydrometallurgical Residue Facility at Maximum <to prepare this figure following the revised project description and geotechnical data packages>

<Additional figures may be included if appropriate based on the data available in version 2 of the geotechnical data packages and management plans.>